Assessing the Emission Benefits of Renewable Energy and Energy Efficiency using EPA's AVoided Emissions and geneRation Tool (AVERT)

AVERT
AVoided Emissions and geneRation Tool
www.epa.gov/avert

EPA Emissions Inventory Conference
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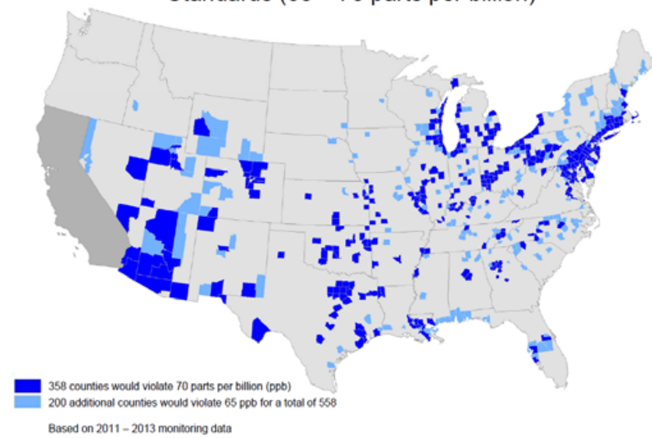
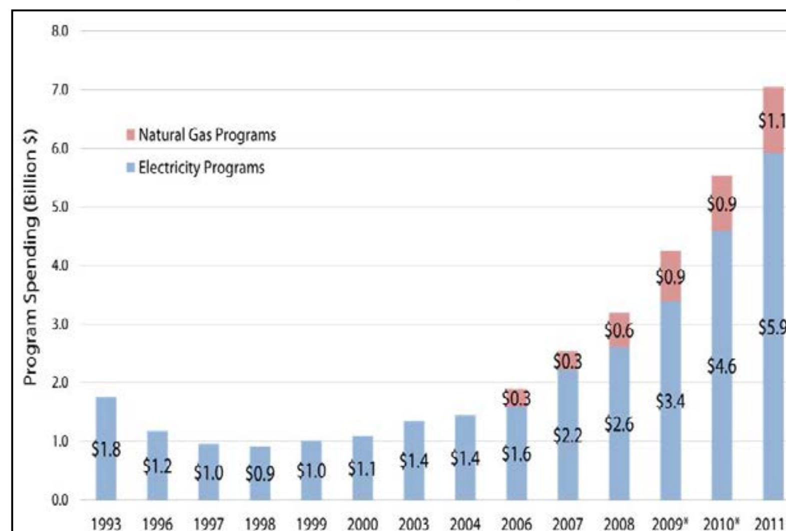
Introduction

- State air quality planners are looking for new ways to reduce emissions, improve air quality
- Meanwhile, states and utilities are advancing proven energy efficiency and renewable energy (EE/RE) policies and programs
- Opportunity for states to include the emissions benefits in air quality plans
- But needed to remove a key barrier – emission quantification of energy impacts

Counties Where Measured Ozone is Above Proposed Range of Standards (65 – 70 parts per billion)



Energy Efficiency Spending



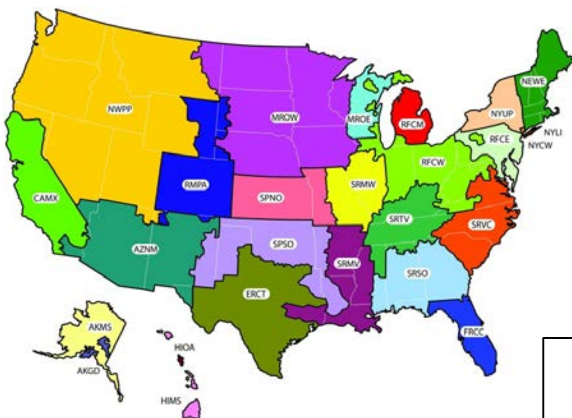
ACEEE 2011

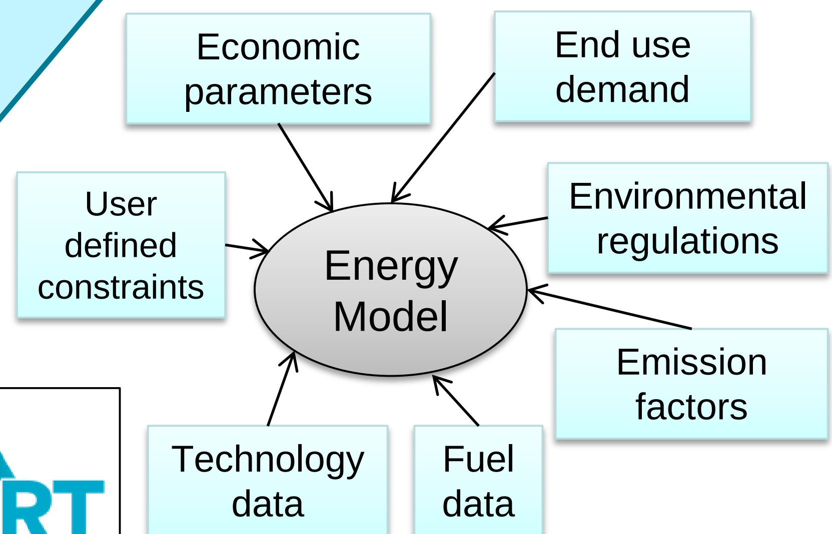
AVERT (AVoided Emissions and geneRation Tool)

- AVERT addresses key challenges associated with quantifying emission benefits of EE/RE programs.
  - Integrated nature of the power system makes it difficult to quantify generation and emissions changes from EE and RE (wind and solar)
  - Generating units, and thus emissions (CO_2 and local/regional air pollutants), respond differently to different programs (EE/RE);
- AVERT translates the energy savings and renewable generation of state EE/RE programs into emission reductions for NAAQS compliance
  - An Excel-based tool that allows users to understand the effect of EE and RE on emission changes at the regional, state, county and EGU levels
  - Built to be straightforward, transparent and credible
  - Peer reviewed and benchmarked against industry standard electric power sector model – PROSYM

Methodology: EPA Develops AVERT

Basic Method	Intermediate Method	Sophisticated Method
Regional displaced emission rates	Historically Hourly emission rates	Energy System Modeling





Methodology: Overview of AVERT

Modules and Data Files

Raw Hourly Generation and Emissions Data from Air Markets Program (AMP) Dataset

Text files

Future Year Scenario Template

User interface for retirements, additions, and retrofits

Excel workbook

AVERT: Statistical Module

Inputs AMP data, performs statistical analysis, outputs new Regional Data Files

MATLAB Code

Regional Data Files

Contains annual hourly load data and unit-level statistics on generation and emissions data

Text files

AVERT Main Module

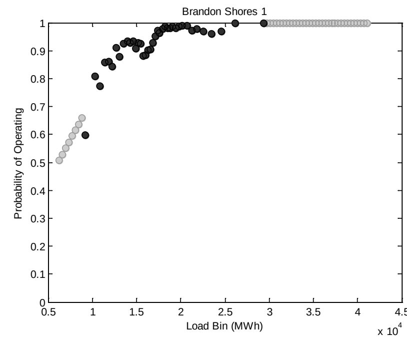
User interface for creating EE/RE load curves, performs displaced emissions analysis, creates output charts and tables

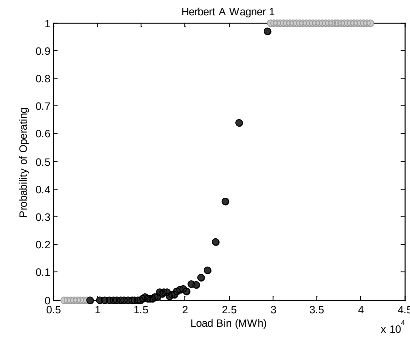
Excel workbook

Most users will only need to use the Regional Data Files and AVERT Main Module to calculate emissions

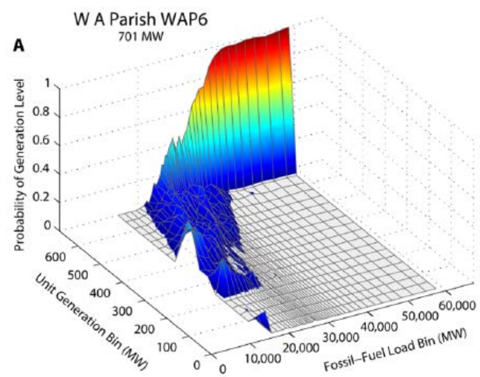
Methodology: The AVERT Algorithm

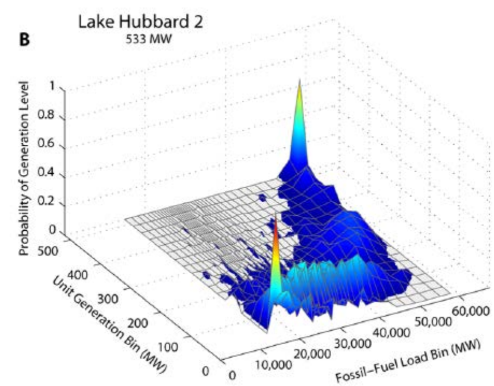
***1)** Determine **Fraction of Time Units are Online** at different load requirements*



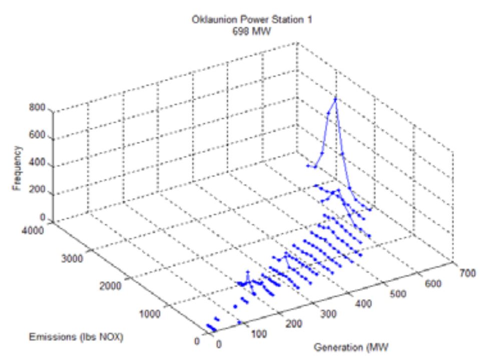


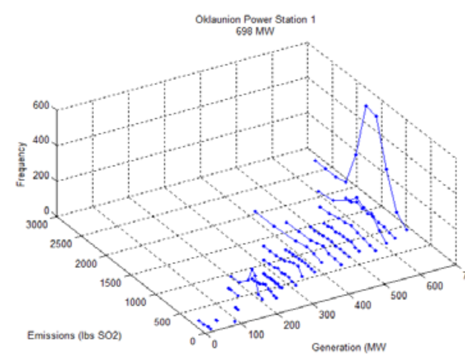
***2)** Determine **Generation** of Units at different load requirements*





***3)** Determine **Emissions Level** at Generation Output*



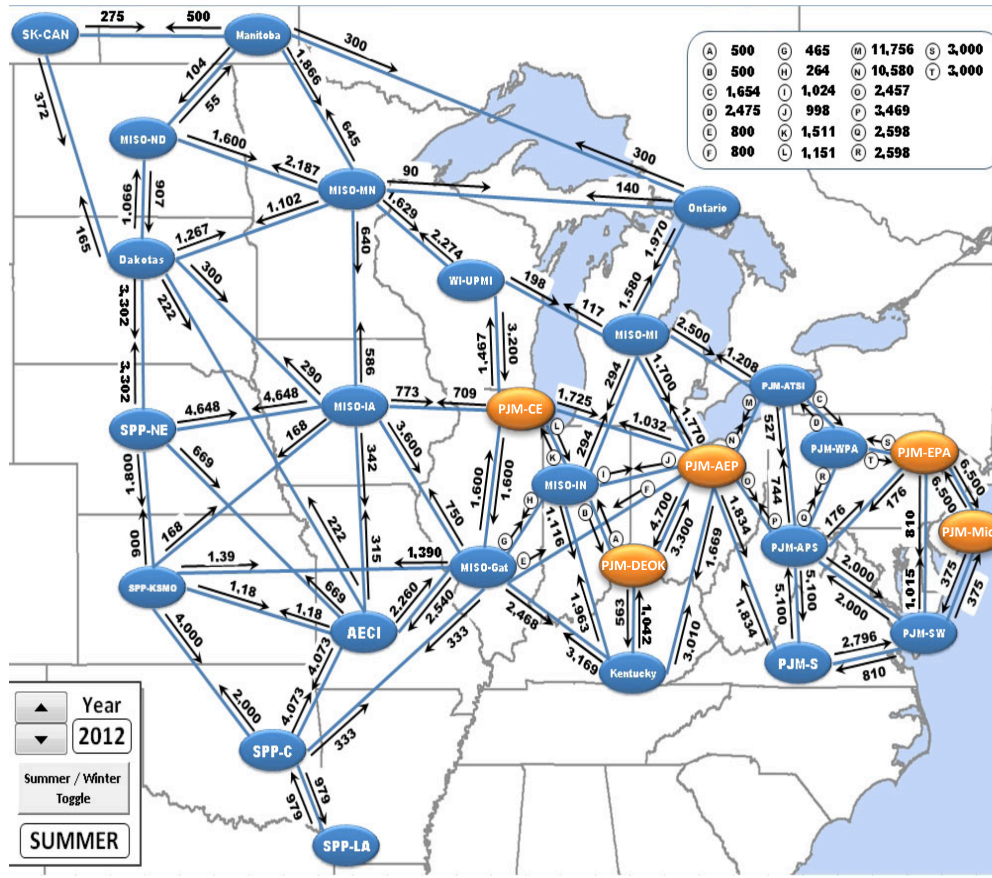


Methodology:

Benchmarking to Industry Standard

AVERT is benchmarked to the PROSYM engine in Market Analytics

- Hourly simulation dispatch model from ABB (formerly Ventyx)
- Industry standard tool for production cost modeling
- Individually tested EE programs in five discrete zones within the PJM interconnect



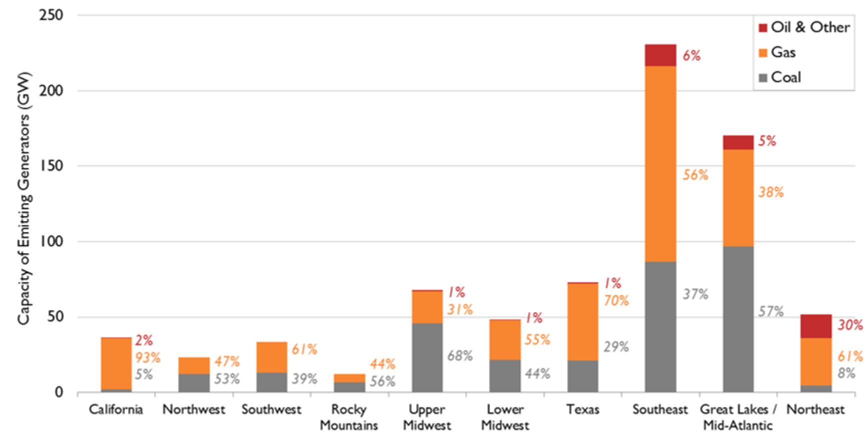
Market Analytics zones in central Eastern Interconnect (does not represent New England or Southeast)

Research Question

- What role do electricity-sector EE and RE resources play in avoiding emissions in regions across the U.S.?
  - Are energy efficiency, wind, or solar resource options most effective for avoiding emissions?
  - Are certain resource options more effective at avoiding CO_2 or NO_x?
  - Are certain U.S. regions more responsive to EE/RE resource options with respect to avoided emissions?
  - What is the variation in avoided emissions at the county level?

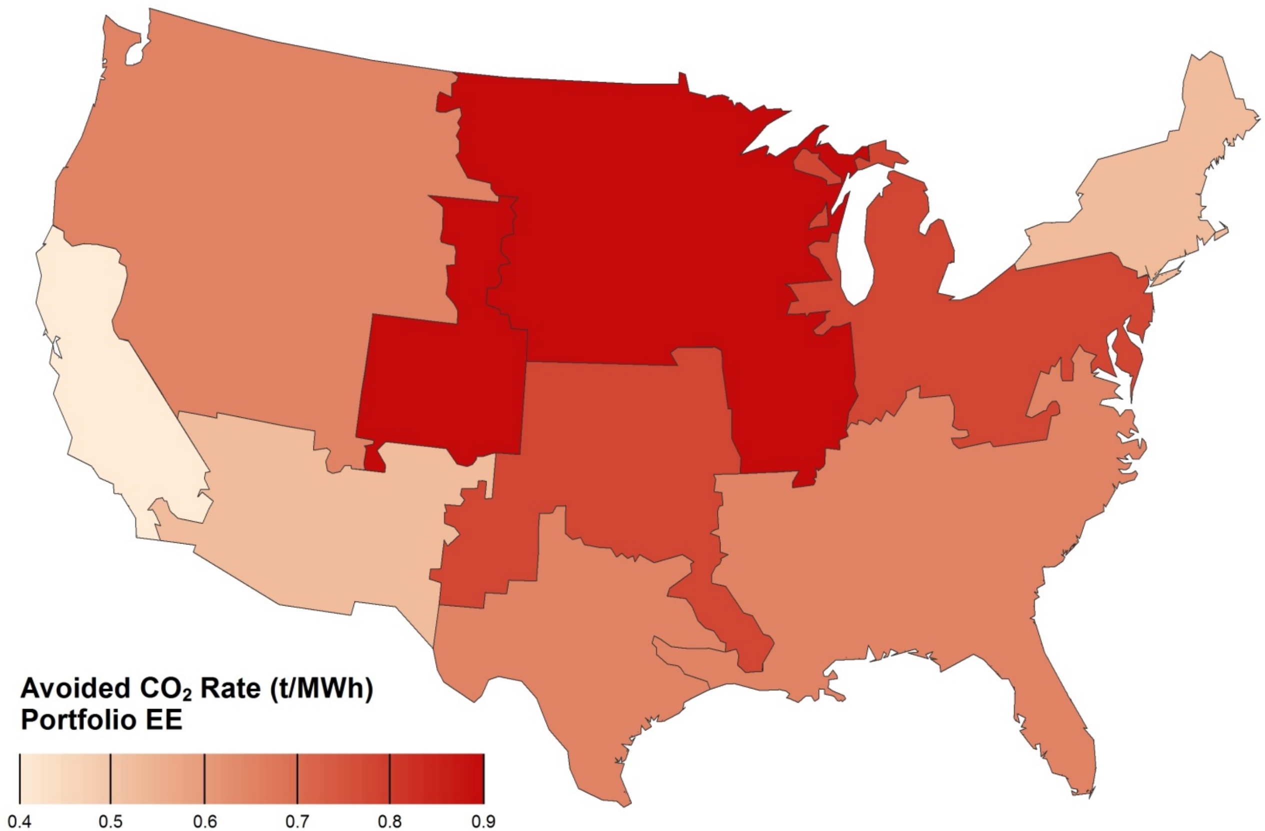
Methodology: Case Study Description

- We compare the effect of four resource options on avoided emissions across AVERT's 10 regions.
  - A portfolio EE program
  - A base load EE program
  - Wind
  - Utility scale solar PV



- As each AVERT region has a unique underlying energy supply resource base, and system size, we apply each resource option as an "equivalent" % avoided generation (% avoided MWh).
- We present results from a 3% avoided generation scenario here.
- We also present detailed county-level avoided NO_x emissions against proposed ozone non-attainment areas in the Great Lakes-Mid Atlantic region, to demonstrate the capabilities of AVERT and suggest future research opportunities.

Results: Avoided CO_2 Emissions Across the U.S. from 3% Energy Efficiency[1]



[1] *Results show displaced emissions from a 3% avoided generation equivalent "portfolio" energy efficiency program.*

Results: Impact of EE/RE Across U.S. Regions

Avoided CO2 Rate (t/MWh)				
	Wind	Utility PV	Portfolio EE	Baseload EE
Northeast	0.52	0.53	0.54	0.53
Great Lakes / Mid-Atlantic	0.78	0.77	0.77	0.77
Southeast	0.66	0.67	0.67	0.67
Lower Midwest	0.82	0.78	0.79	0.81
Upper Midwest	0.91	0.89	0.89	0.90
Rocky Mountains	0.85	0.83	0.83	0.84
Texas	0.67	0.64	0.64	0.66
Southwest	0.57	0.56	0.56	0.56
Northwest	0.68	0.68	0.66	0.68
California	0.49	0.49	0.49	0.49

Avoided NOx Rate (lbs/MWh)				
	Wind	Utility PV	Portfolio EE	Baseload EE
Northeast	0.62	0.68	0.72	0.65
Great Lakes / Mid-Atlantic	1.27	1.30	1.31	1.29
Southeast	0.97	1.02	1.02	1.00
Lower Midwest	1.59	1.62	1.61	1.60
Upper Midwest	1.55	1.54	1.54	1.54
Rocky Mountains	1.63	1.56	1.57	1.59
Texas	0.66	0.68	0.68	0.67
Southwest	0.91	0.85	0.79	0.84
Northwest	1.32	1.35	1.38	1.37
California	0.73	0.70	0.67	0.70

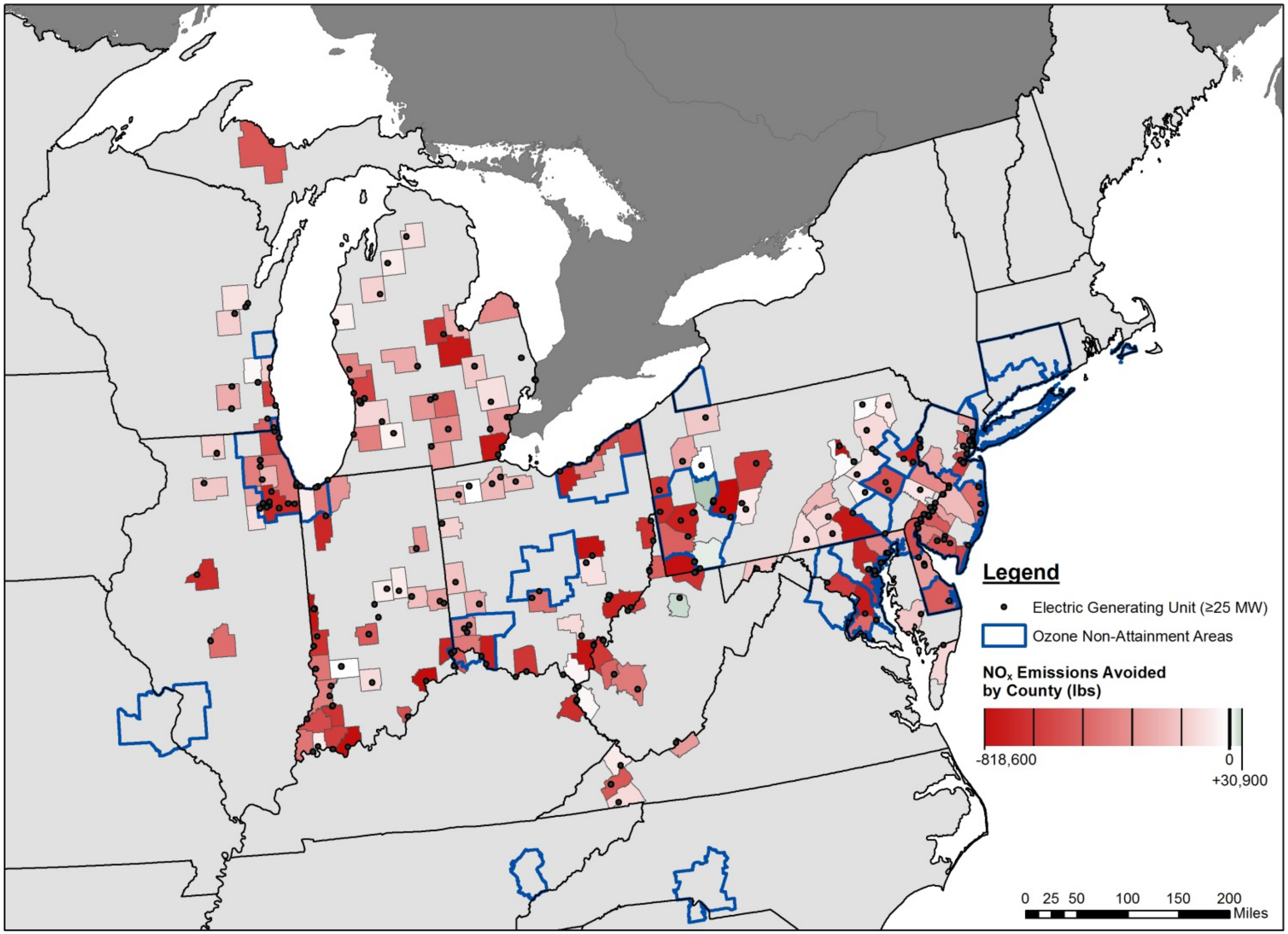
Across EE and RE options

- ***Wind*** *and* ***Baseload EE*** *create the highest level of displaced CO_2 emissions per MWh avoided*
- *There is* ***more variation*** *in the effect of programs on displaced NO_x emissions per MWh avoided*

Across US Regions

- *Regions with a disproportionately* ***high coal resource base*** *(i.e., Midwest, Great-Lakes, and Rockies) experience the greatest emission displacements*

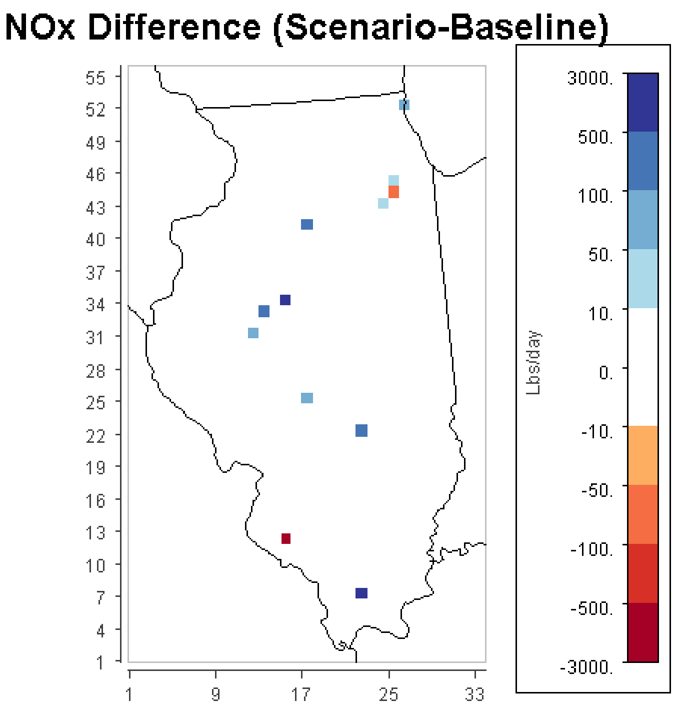
Results: Avoided NO_x Emissions from EE in the Great Lakes-Mid Atlantic Region during Ozone Season



Next Steps: Regional Air Quality Impacts from Avoided Emissions

Next research question:

- What are the air quality benefits of renewable energy installations in the Eastern US?
  - Assess ozone benefits of wind and solar installations
  - Project future air quality impacts in 2018 using CMAQ
- AVERT can produce output files for the **Sparse Matrix Operator Kernel Emissions (SMOKE)** modeling system
  - Designed to create gridded, speciated, hourly emissions for input into air quality models such as CMAQ, REMSAD, CAMX and UAM.



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Questions?

Selected References

- Bettle, R., Pout, C.H., and E.R. Hitchin. 2006. Interactions Between Electricity-Saving Measures and Carbon Emissions from Power Generation in England and Wales. Energy Policy 34: 3434-3446.
- Cullen, J. 2013. Measuring the Environmental Benefits of Wind-Generated Electricity. American Economic Journal: Economic Policy 5(4): 107-133.
- Denholm, P., Margolis, RM., Milford, JM. 2009. Quantifying Avoided Fuel Use and Emissions from Solar Photovoltaic Generation in the Western United States. Env. Science and Technology 43(1): 226-232
- Fisher, J. et al. 2011. Emissions Reductions from Energy Efficiency and Renewable Energy in California Air Quality Management Districts. California Energy Commission Report CEC-500-2013-047.
- Hausman, E., Fisher, J., and B. Biewald. 2008. Analysis of indirect emissions benefits of wind, landfill gas, and municipal solid waste generation. EPA/600/R-08-087.
- Hawkes, A.D. 2010. Estimating Marginal CO_2 Emission Rates for National Electricity Systems. Energy Policy 38: 5997-5987.
- High, C. and G. Neeraj. 2011. Avoided Emissions from the Antrim Wind Project. http://antrim-wind.com/files/2012/03/RSG-Final-Avoided-Emissions-Report.pdf
- Kaffine, D.T., McBee, B.J., and J. Lieskovsky. 2013. Emission Savings from Wind Power Generation in Texas. The Energy Journal 34(1): 155-175.
- Kerr, T., Morgan, R., Haydel, J., and B. Thapa. 2002. Average Displaced Emission Rate (ADER): Approach and Methodology. Presented at 11th International US EPA Emission Inventory Conference - "Emission Inventories - Partnering for the Future“.
- Newcomer, A., Blumsack, SA., Apt, J., Lave, LB., and MG Morgan. 2008. Short Run Effects of a Price on Carbon Dioxide Emissions from U.S. Electric Generators. Env. Science and Technology 42 (9): 3139–44.
- Rekkas, D., 2005. UK marginal power plant and emissions factors. Centre for Environmental Policy, London, UK, Imperial College London, MSc.
- Rothschild, S. and A. Diem. 2009. Total, Non-baseload, eGRID Subregion, State? Guidance on the Use of eGRID Output Emission Rates. 18th Annual International Emission Inventory Conference "Comprehensive Inventories -Leveraging Technology and Resources". Baltimore, MD.
- Siler-Evans, K., Azevedo, IL., Morgan, MG., and J. Apt. 2013. Regional Variations in the Health, Environmental, and Climate Benefits of Wind and Solar Generation. PNAS 110 (29): 11768-11773.
- Valentino, L., Valenzuela, V., Botterud, A., Zhou, Z., and G. Conzelmann. System-Wide Emissions Implications of Increased Wind Power Penetration. Env. Science and Technology 46: 4200-4206.
- Zhai, P., Larsen, P., Millstein, D., Menon, S., and E. Masanet. 2012. The Potential for Avoided Emissions from Photovoltaic Electricity in the United States. Energy 47: 443-450.

Methodology:

Simple Methods to Evaluate Avoided Emissions

- **Average emissions rate** of all operating EGUs in a region
  - *May underestimate avoided emissions in regions with many non-emitting (and non-marginal) EGUs*
  - *No temporal or spatial resolution*
- Emissions rate from **a single "marginal unit,"** or **cohort of historical marginal units** based on **pre-determined "merit orders"** (e.g., Rothschild & Diem 2009; High & Neeraj. 2011; Hausman, Fisher, & Biewald 2008; Bettle, Pout, & Hitchin 2006; Newcomer et al. 2008; Cullen 2013; Kaffine, McBee, & Lieskovksy 2013)
  - *Requires implicit (or explicit) assumptions about unit operations which do not always hold*
- Calculate a **"slope factor"** (best-fit line) for the relationship between historical generation and emissions (e.g., Hawkes 2010; Hausman, Fisher, & Biewald 2008; Siler-Evans et al. 2013; Rekkas 2005)
  - *This method can be highly aggregated (e.g., into technology types) and often blurs temporal patterns in electricity demand and supply*

Methodology:

Model-Based Methods to Evaluate Avoided Emissions

- Use a **regional model** to estimate how "blocks" of EGUs respond to changes in generation (e.g., EPA ADER Model 2002; Zhai et al. 2012)
  - *Blocks are determined from coarse resolution models with non-chronological dispatch*
- Use a detailed **electricity dispatch optimization model** to test how EGUs respond to changes in renewable energy and/or energy efficiency (e.g., Denholm, Margolis & Milford 2009; Valentino et al. 2012)
  - *Increased detail/precision can come at the expense of model accessibility*